Geological Survey of Victoria

GROUNDWATER FOR GEELONG:

FURTHER MODELLING OF THE GERANGAMETE WELLFIELD

By R BLAKE

UNPUBLISHED REPORT 1980/107

DEPARTMENT OF MINERALS AND ENERGY

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CONTENTS

Introduction

This report is in response to a request by the Geelong Waterworks and Sewerage Trust for further drawdown computations on the wellfield layout designed for the Barwon Downs Sub-basin. The possible bore locations in the wellfield differ slightly from those given in the original design (Blake, 1978) and were optimized for the purpose of pipeline design. The bore positions are shown plotted on Fig 1 and for reference see GWW & ST plan No 23028.

In the original wellfield design it was recommended that a further two or three production bores could be drilled in addition to GW1 and GW2. The new wells should be located in the vicinity of GW2 at approximately one kilometre spacings from GW2 and it was recommended that each bore could be pumped at rates of up to 92.6 l sec^{-1} (8 Ml day^{-1}). This would achieve an annual yield of 11 680 Ml for a field of four bores (including GW1 and GW2) or an annual yield of 14 600 Ml for a field of five bores.

The present estimate of natural recharge and flow through the Sub-basin was calculated at approximately 8000 Ml $year^{-1}$ (Blake, 1974). On the basis of this estimate the Department of Minerals and Energy has given approval for extraction from the Barwon Downs Sub-basin of up to 12 500 Ml $year^{-1}$ in any one year but not to exceed 80 000 Ml over a period of ten years. It was considered that the license for extraction could be revised on the basis of several years operation of the field. The basis for reviewing the licensed extraction would be a study of the effects of possible induced recharge in the intake areas following development.

In a report to the Trust by the Trust's consultants (A.G.C., 1978) a revised estimate of recharge and yield was made in which it was suggested that the basin could yield 23 000 Ml $year^{-1}$ following development rather than the presently estimated 8000 Ml $year^{-1}$. On the basis of this higher estimate it was recommended by the consultant that a further five bores could be drilled (in addition to the existing GW1 and GW2) and that each production bore could be pumped at 110 l sec^{-1} (9.5 Ml day^{-1}) for a total annual yield of 23 000 Ml. It was also recommended by the consultant that the field could be developed in two stages, the first stage to comprise a total of four bores and the second stage a total of seven bores.

Drawdown Calculations

On the basis of the consultants recommendations the Trust has requested the Department of Minerals and Energy to make further drawdown calculations on a wellfield comprising either four, six or seven bores all pumping at 110 l sec^{-1} (9.5 Ml day^{-1}). The exact conditions to be modelled are contained in a letter from the Trust to the Director of the Geological Survey reproduced here in Appendix 1. The conditions can be summarized as follows (for bore locations refer Fig 1).

i) Operating bores GW1, GW2, GW3, GW4, GW5, GW8 and GW11 at 110 l sec^{-1} for a) one year and b) two years.

ii) As for i) but with GW3 omitted.

iii) Operating bores GW1, GW2, GW4 and GW5 at 110 l sec^{-1} for a) one year and b) two years.

iv) The capacity from the bores listed in iii) but with drawdowns increased to be within the values obtained for ii).

It was requested that recharge be taken into account but the amount of recharge to be assumed was not specified. Because the drawdown for each bore in the wellfield is dependent on the rate of recharge in the intake area, a recharge rate had to be assumed for each case modelled. Two conditions were assumed:

i) Rate of total recharge (natural and induced) equal to the total extraction rate from the field (up to a total of 24 280 Ml $year^{-1}$).

ii) Rate of total recharge equal to only the presently estimated natural flow-through the basin (i.e. 8000 Ml $year^{-1}$).

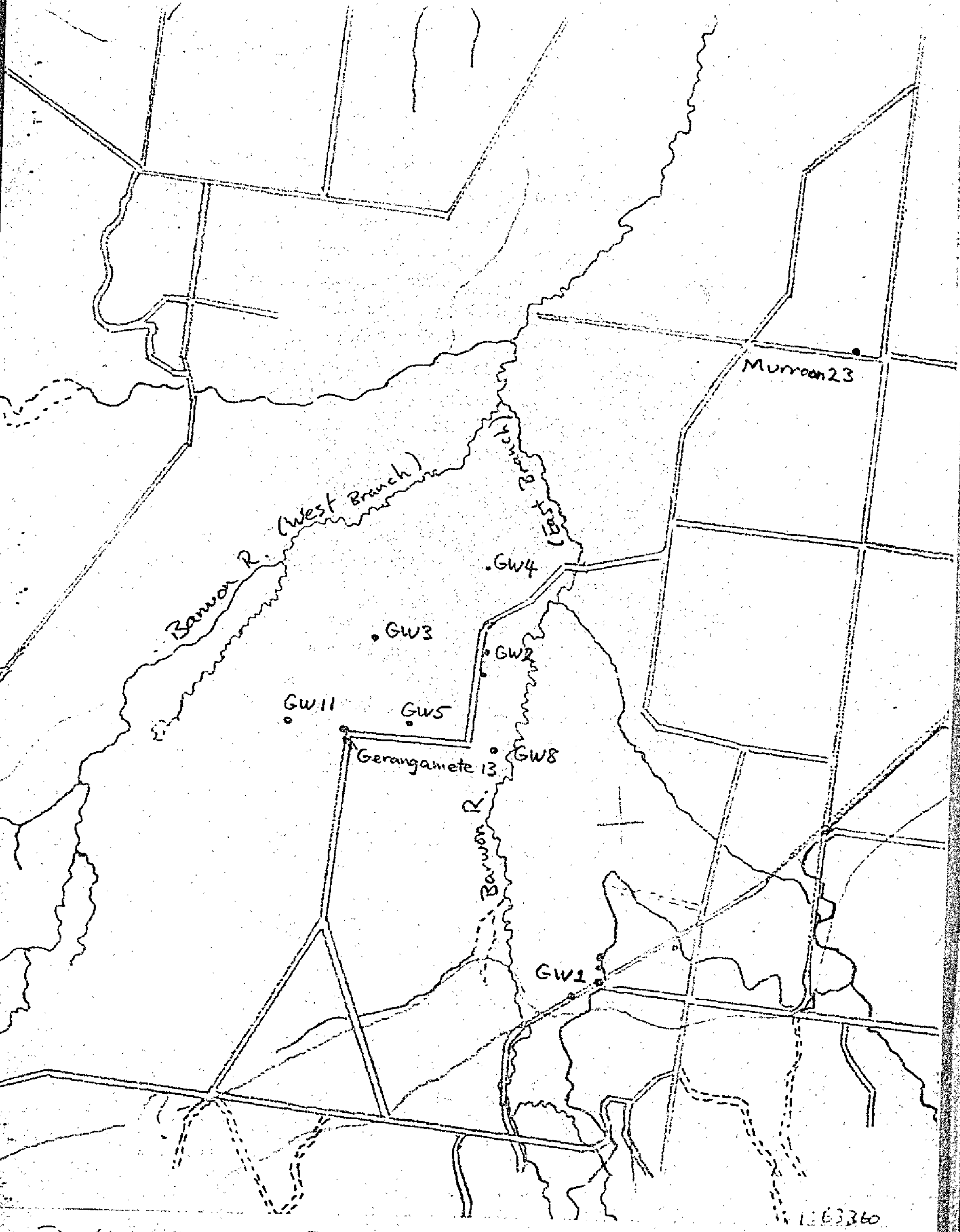

Fig. 1 Alternative Bore location for the Gerangamete Wellfield

Computer Program for Wellfield Design

The wellfield calculations were carried out on a desk top computer using a program written specifically for the Barwon Downs project (Blake, 1978). A description of the program is included here in Appendix 2. An important feature of the program is that both recharge and discharge boundaries can be allowed for by image well theory. The same hydrogeological conditions as assumed in the 1978 report were modelled (i.e. the Bambra Fault discharge boundary and the Barongarook Intake area recharge boundary). The rate of recharge allowed for can be varied simply by changing the recharge rate of individual recharge wells on the recharge boundary. The basic input and required parameters for each of the wellfield runs include the following

i) Transmissivity, $T = 510\ m^2\ day^{-1}$ and
Storage Coefficient, $S = 3 \times 10^{-4}$

ii) Radius of pumping bores, $R = 0.1$ m (at the screens)
Well loss coefficient, $C = 3.21 \times 10^{-7}\ m^{-5}\ day^2$

iii) Coordinates (in metres) of all bores (including recharge image wells and discharge image wells). These were obtained by scaling from plan No. 23028 and are correct to $\pm$ 50 m.

Well Loss

The program calculates well loss from the function CQ^2 where

C = Well loss coefficient in $m^{-5}\ day^2$

and Q = Discharge in $m^3\ day^{-1}$

The results of the wellfield calculations are tabulated as total drawdown in each pumping bore in metres and the results include a value for well loss.

To calculate the drawdown in each bore due to only the aquifer and to interference from other wells subtract the well loss function CQ^2.

The value of the well loss coefficient input to each well field run was the value estimated by the Trust's consultant on the basis of a larger diameter transmission casing being used for the new production bores. In order to correct the total drawdowns in GW1 and GW2 for the actual well loss coefficients rather than the estimated value the following well loss coefficients are applicable.

GW1 :- $C = 1.54 \times 10^{-7}\ m^{-5}\ day^2$

GW2 :- $C = 5.0 \times 10^{-7}\ m^{-5}\ day^2$

For example the following calculation corrects the drawdown in GW2 in Table 3 after pumping for one year to allow for the observed well loss coefficient rather than the assumed well loss coefficient.

$$\text{Drawdown} = 102.6 - (3.21 \times 10^{-7} \times 9504^2) + (5 \times 10^{-7} \times 9504^2)$$
$$= 118.8\ m$$

It should be noted that the units for pumping rate Q, are in $m^3\ day^{-1}$ not $l\ sec^{-1}$.

Results

Tables 1 to 7 present the results of the drawdown calculations tabulated as total drawdown in metres for each bore for each of the conditions i) to iv) requested. Tables 1, 2, 3 and 6 present the results with the assumption that total recharge (i.e. natural and induced) is equal to the extraction rate. Tables 4, 5 and 7 summarize the results for conditions i), iii) and iv) with the assumption that total recharge is equal to 8000 Ml $year^{-1}$.

Table 1. Seven pumping bores at 110 l sec^{-1} per bore with recharge assumed equal to the extraction rate (i.e. 24 280 Ml/year)

Years	GW1	GW2	GW3	GW4	GW5	GW8	GW11
1	138.9	134.8	128.7	128.3	136.3	137.8	124.1
2	146.3	142.1	135.9	135.5	143.5	144.9	131.3
3	150.6	146.3	140.2	139.7	147.7	149.1	135.5

Table 2. Six pumping bores at 110 l sec^{-1} per bore with recharge assumed equal to the extraction rate (i.e. 20 814 Ml/year)

Years	GW1	GW2	GW4	GW5	GW8	GW11
1	129.4	124.3	118.0	124.8	127.2	114.1
2	135.8	130.6	124.2	131.1	133.5	120.3
3	139.5	134.2	127.8	134.7	137.1	123.9

Table 3. Four pumping bores at 110 l sec^{-1} per bore with recharge assumed equal to the extraction rate (i.e. 13 876 Ml/year)

Years	GW1	GW2	GW4	GW5
1	107.4	102.6	99.0	101.0
2	111.6	106.7	103.2	105.1
3	114.9	109.2	105.6	107.6

Table 4. Seven pumping bores at 110 l sec^{-1} per bore but with total recharge assumed equal to 8000 Ml/year

Years	GW1	GW2	GW3	GW4	GW5	GW8	GW11
1	155.4	155.2	150.4	149.5	156.4	157.1	145.3
2	167.4	167.1	162.2	161.4	168.3	169.0	157.1
3	174.4	174.0	169.1	168.3	175.3	175.9	164.0

Table 5. Four pumping bores at 110 l sec^{-1} per bore but with total recharge assumed equal to 8000 Ml/year

Years	GW1	GW2	GW4	GW5
1	113.2	109.7	106.4	108.1
2	119.1	115.5	112.3	114.0
3	122.5	118.9	115.7	117.4
5	126.9	123.3	120.0	121.7

Table 6. Four pumping bores pumping at different rates for one year with recharge assumed equal to the extraction rate in each case

l sec^{-1}	GW1	GW2	GW4	GW5	Annual Recharge (Ml)
120	120.0	114.8	110.9	113.0	15 137
125	126.5	121.1	117.0	119.2	15 768
130	133.1	127.5	123.2	125.6	16 399
140	148.7	140.6	136.1	138.6	17 660

Table 7. Four pumping bores pumping at different rates for one year but with total recharge assumed equal to 8000 Ml/year in each case

l sec^{-1}	GW1	GW2	GW4	GW5
110	113.2	109.7	106.4	108.1
120	127.3	123.7	120.3	121.9
130	141.7	138.0	134.3	136.8

Each condition modelled was run for three years rather than the two years requested to demonstrate the fact that equilibrium will not be achieved even at the higher rates of assumed recharge.

The effects of reducing the assumed recharge can be seen by comparing Table 1 and Table 4. The results show for example, that drawdowns are an average of 20 m greater in each pumping bore for reduced recharge after one years pumping for a wellfield comprising seven production bores. Similarly, comparing Tables 3 and 5 the drawdowns are on average 7 m greater in each pumping bore with reduced recharge in a wellfield of four production bores after one years pumping.

Table 6 presents the results of several wellfield runs to test for the effect of varying capacities for condition iv). The results indicate that the individual pumping rates could be increased to approximately 125 l sec^{-1} for the bores listed in condition iii) to achieve the drawdowns within the values obtained for condition ii). Examination of Table 7 on the other hand suggests rates could only be increased to 120 l sec^{-1} to achieve the same result if the lower recharge rate is assumed.

Finally in order to calculate the actual drawdown below ground level in each bore an average value of + 160 m A.H.D. for the reduced level of the potentiometric surface over the area of the wellfield can be assumed.

Conclusion

The ultimate development potential of the Barwon Downs Sub-basin is dependent upon the amount of natural recharge and the amount of recharge which can be induced following development of the basin. Initially there will also be an additional contribution from storage until the basin achieves a new equilibrium. The consultant to the Trust suggests that up to 15 000 Ml per year of recharge can be induced by development of the Gerangamete wellfield. Some caution is required however in suggesting such large amounts of induced recharge because experience in similar basins elsewhere in Victoria suggests much lower rates of induced recharge are possible.

The Westernport Basin to the east of Melbourne is similar in size and area to the Barwon Downs Sub-basin and similarly fault bounded. The depth to the aquifer is less but the thickness of total aquifer is similar. Average yearly extraction from the Westernport Basin is 11 000 Ml from approximately 260 irrigation bores and 1280 stock and domestic bores. This relatively small amount of extraction has induced saline water into the aquifer both from seawater intrusion and onshore sources by a process of gradient reversals and a situation of overdevelopment is considered to exist (Lakey, 1980). A similar situation of overdevelopment exists in the Latrobe Valley Sub-basin. The major source of groundwater extraction is dewatering of the Morwell open cut mine. Total extraction is currently 30 000 Ml per year and a situation of overdevelopment is occurring. The cone of depression extends to at least 56 km to the east where water levels are currently dropping at a rate of 1.1 m per year. At Traralgon 15 km to the east water levels are dropping at a rate of 2.9 m per year (Reid, pers. comm.). These rapid falls in water level are occurring inspite of a demonstrable recharge effect from the Baragwanath Anticline to the south of Rosedale and Sale which is a major intake area. Although not as well documented even when extraction rates were half those of the present rates ten years ago, it was considered that extraction was exceeding recharge and that much of the water was being produced from storage. The Latrobe Valley Sub-basin is larger in size but similar in structural development (i.e. fault bounded) to the Barwon Downs Sub-basin.

The final safe yield from the Barwon Downs Sub-basin should be determined from a study of intake in the Barongarook area. Although equilibrium may not be achieved for some time in the deeper parts of the basin a new equilibrium should be established in the intake area relatively quickly and should be observed in monitoring bores recently established in the area. A study of baseflows from streams which drain the intake area, particularly the Boundary Creek, should also help to quantify the amount of possible induced recharge which can be diverted from present surface runoff to groundwater. The original wellfield design of four to five bores all pumping at 8.0 Ml day^{-1} is capable of producing 11 680 Ml per year from four bores or 14 600 Ml per year from five bores. If individual pumping rates are increased to 9.5 Ml day^{-1} the yield from four bores is 13 870 Ml per year and from five bores is 17 338 Ml per year. Although as yet there is no data upon which to precisely estimate the amount of induced recharge it is unlikely that the yield from the basin will increase 300 percent (from 8000 to 23 000 Ml per year). A more probable figure might be in the range 50-100 per cent. The original wellfield design should therefore be capable of producing all the available water from the Barwon Downs Sub-basin unless other, at present unidentified, sources of recharge exist.

REFERENCES

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Appendix 1.

Request for further modelling.

GWST
Geelong Waterworks & Sewerage Trust • 61-67 Ryrie Street, Geelong • P.O. Box 659, Geelong, Vic. 3220 • Telephone 26 2500

JRJ/AK

October 21, 1980

The Director of Geological Survey,
Department of Minerals and Energy,
107 Russell Street,
MELBOURNE VIC 3000

Attention Mr. R. Blake

Dear Sir,

Details of the Trust's resolution to complete Stage 1 of the Barwon Downs Groundwater Project were forwarded to the Department on October 8, 1980 (ref. GNSE/AK).

The existing bores GW1 and GW2, the proposed bores GW4 and GW5, together with pipeline and treatment plant proposals are shown on plan 23028 which is enclosed.

Depending on a revised assessment of recharge and yield after operating Stage 1 for a number of years, it would be desirable to install a further three production bores in accordance with the recommendations by Australian Groundwater Consultants Pty. Ltd. (December 1978). In accordance with discussions between Mr. Jackson of the Trust and Mr. Blake on October 20, 1980, the depth of pump well and specifications for submersible pumps, based on current predictions of storage and recharge behaviour, must allow for the drawdown effects from operation of up to seven bores.

It would therefore be appreciated if drawdown computations for the proposed bore layout could be carried out by your Department for the following conditions:

1. Operating bores GW1, GW2, GW3, GW4, GW5, GW8 and GW11 at 110 L/sec for (a) 1 year and (b) 2 years;

2. As for (1) but with GW3 omitted;

3. Operating bores GW1, GW2, GW4 and GW5 at 110 L/sec for (a) 1 year and (b) 2 years.

4. The capacity from the bores listed in (3) but with drawdowns increased to be within the values obtained for (2).

The assumed static water level at each bore is also required in order to obtain depths below ground level at each bore.

Yours faithfully,

J R Jackson

J.R. Jackson,
Senior Engineer,
[illegible]

Appendix 2.

Computer Program for well field design

The procedure normally used to calculate interference between bores involves a prohibitive amount of calculation if a number of various well field designs are to be compared and if calculations are performed by hand. For this reason a program was developed for the HP 9815A Desktop computer and plotter which duplicates the procedures which would normally be done manually. The program developed is as follows.

The drawdown at any point distance r from a pumping well in a confined aquifer is given by the Theis equation

$$s = \frac{Q}{4\pi T} \int_{\mu}^{\infty} \frac{e^{-y}}{y}\, dy$$

$$= \frac{Q}{4\pi T} \quad Wu$$

The integral Wu, or the well function of u, expands to the following infinite series

$$Wu = 0.577216 - \ln u + u - \frac{u^2}{2x2!} + \frac{u^3}{3x3!} - \frac{u^4}{4x4!} \ldots\ldots$$

where $u = \frac{r^2 S}{4\ Tt}$

Q = Pumping rate in $m^3\ day^{-1}$

s = Drawdown in metres

r = Distance in metres

t = Time since pumping started in minutes

T = Coefficient of Transmissivity in $m^2\ day^{-1}$

S = Coefficient of Storage - dimensionless

The drawdown in a pumping bore in a well field is the arithmetic sum of the drawdown due to itself pumping in the aquifer, s_{aq}, plus the sum of the drawdowns due to every other bore in the well field, s_{int}, plus the drawdown due to the well loss in the bore itself, s_{self}

$$\text{i.e. } s_{TOT} = s_{saq} + s_{int} + s_{self}$$

Briefly, the program involves entering and storing the metric coordinates and individual pumping rate of each bore in the well field, together with the T and S of the aquifer, the radius of the pumping bores and the well loss coefficient. The distance of each pumping bore to every other pumping bore can then be calculated from the coordinates and the drawdown at this distance calculated from the Theis expression. The interference drawdowns so calculated are summed and added to the self caused drawdown and the well loss for each bore. The total drawdowns are then printed and also plotted on the plotter at the correct locations to provide an immediate visual interpretation of the results.

The drawdown at any point in the aquifer (e.g. an observation bore) can also be calculated simply by entering a zero pumping rate together with the coordinates for this point.

Hydrogeological boundaries can be allowed for by image well theory (i.e. by inserting another bore in the field at a distance equal to the distance of the pumping bore to the boundary but on the other side of the boundary). In the case of recharge boundaries the drawdowns due to recharge image wells must be subtracted rather than added to the total drawdown and this was allowed for in the program.

The time which it is required to pump the well field can also be varied i.e. the program does not return to the start when a well field calculation is completed but instead allows the same well field configuration to be pumped at the same rate but for a different time.

The main advantage of the program over other numerical models is that it is very simple and rapid to use and allows large numbers of various well field configurations to be tested.

The main disadvantage of the program is that T and S of the aquifer cannot be varied throughout the aquifer and the model is therefore subject to the constraints placed on it by the Theis equation.